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Unsuitability of sump tubes for delivery of enteral nutrition and medications to intensive care unit patients

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ABSTRACT

16 Fr Salem Sump™ tubes have special features to facilitate suction drainage of the stomach, including a second lumen for air venting. These tubes are also commonly used to deliver enteral nutrition and medications to intensive care unit (ICU) patients, but we found no previous research to justify this practice. Because of the unused air vent, these tubes have a large external diameter and a small bore infusion channel (no larger than that of a single lumen 12 Fr feeding tube). The causes of 16 Fr Salem Sump tube obstructions in 17 ICU patients included clogged medications (8 cases) and precipitation of feeding formula (7 cases), each of which would be promoted by a narrow bore. Because of multiple drainage holes at their distal end, these tubes cannot be thoroughly cleansed by standard water flushing; moreover, their drainage holes mandate a deeper length of tube insertion beyond the gastroesophageal junction, which increases the likelihood of intestinal or pulmonary perforation. For these reasons, we conclude that 16 Fr Salem Sump tubes are inferior to standard feeding tubes for delivery of enteral nutrition and medications to patients in medical ICUs.

KEYWORDS Acid-induced precipitation of formula; complications of enteral nutrition; crushed medications; nasogastric tubes; Salem Sump tubes

In the early days of enteral nutrition, delivery of enteral formula through a nasogastric tube was preceded by aspiration of stomach contents to measure residual gastric volume. At that time, Salem Sump nasogastric tubes were a reasonable choice for enteral nutrition because they have an air vent to facilitate gastric aspiration, and enteral feeding can be provided through the tube when suction is not being applied. Currently, gastric residual volume is not measured in patients receiving enteral nutrition, in part because aspiration of acidic gastric juice is believed to contribute to obstruction of feeding tubes. However, 16 Fr Salem Sump tubes continue to be routinely used for delivery of enteral nutrition and medication in many intensive care units (ICUs), including those at Baylor University Medical Center, even though this practice is not recommended by the manufacturer. The purpose of our research was to evaluate whether or not Salem Sump tubes are a reasonable choice for delivery of enteral nutrition and medications now that aspiration of gastric contents is no longer performed.

METHODS

The design of a Salem Sump tube is shown in *Figure 1*. The tube contains two lumens. The larger of the two lumens is oval in shape. The smaller lumen has a single distal opening that shares a common intratube space with several of the distal drainage holes of the larger lumen. The external wall of the tube contains a radiopaque strip with a short deletion located 8 cm from the tip of the tube, which coincides with the most proximal sentinel hole of the larger lumen. The distal end of the tube contains a total of 11 drainage holes within a tube length of 8 cm.

When suction is applied to the larger lumen, gastric fluid is removed, the stomach lumen is reduced, and gastric mucosa may block the opening of the drainage holes. The resulting increase in negative pressure within the tube causes air to enter the air vent and travel in a downward direction to the tip of the tube, and then upward through the aspirating lumen into a collection bottle for gastric fluid. This reduces excess negative pressure in the aspirating lumen and it also sweeps any gastric fluid that was trapped in the aspirating lumen into the collection bottle. This air vent/sump mechanism facilitates

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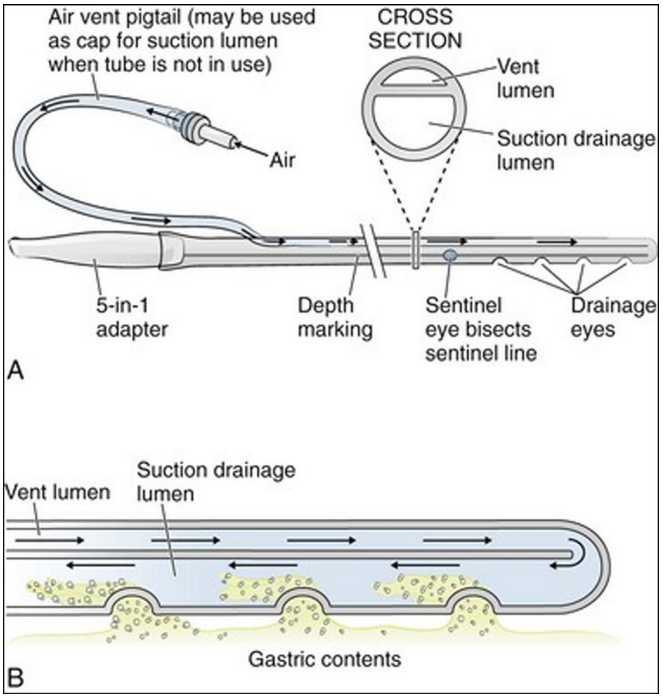

Figure 1. Diagram of a Salem Sump tube. See text in Material and Methods for description. **(a)** General design. **(b)** Diagram of the double-lumen principle of suction. Reprinted from https://clinicalgate.com/nasogastric-and-feeding-tube-placement/; drawing courtesy of the Argyle Division of Sherwood Medical, St. Louis (now Cardinal Health).

collection of gastric fluid and limits excess negative pressure that might cause suction damage to gastric mucosa.

When these tubes are used to deliver enteral nutrition, they are inserted until the sentinel hole of the larger lumen (which we will now refer to as the "infusion lumen") is below the lower esophageal sphincter, as determined by x-ray. At this position, at least 8 cm of the distal infusion lumen and all of its 11 drainage holes reside within the stomach. Nutritional formula or medications infused or injected into the proximal end of the infusion lumen are delivered into the stomach through one or more of its multiple distal holes. The air vent lumen plays no role in the delivery of nutrition or medications, and it remains plugged. The cross-sectional space it occupies reduces the internal diameter of the infusion lumen. As noted in the introduction, the manufacturer of Salem Sump tubes does not approve the use of these tubes for enteral nutrition.[1]

We performed studies on obstructed 16 Fr Salem Sump tubes that were removed from ICU patients. This study was approved by the institutional review board of Baylor University Medical Center. The board determined, in accordance with 45 CFR 46.116 (d), that our examination of obstructed tubes removed from ICU patients did not require informed consent from patients. Obstructed 16 Fr Salem Sump tubes in our ICUs were identified by ICU nurses. The tubes were disconnected from tubing leading to the pump, the proximal openings were plugged, and the tubes were removed from the patients. Acceptance of an obstructed tube into our study depended only on the availability of the authors to promptly examine the tube and obtain the history of the tube from ICU staff and medical records. Obstructed tubes were taken directly to the autopsy department. Plugs were removed from the infusion lumen and fluid was drained. All segments of the tubes were inspected grossly. Cross-sections were taken at 10, 55, and 100 cm from the distal end of the tube. Additional cross-sections were made as necessary to search for obstruction. Photographs and notes were taken and drawings were made. In some cases, clotted material was prepared for hematoxylin and eosin staining and microscopy. Determination of the apparent cause of obstruction was made after consideration of what was being injected or infused into the tube at the time obstruction was recognized, combined with pathological results on obstructed tubes.

In vitro experiments were conducted to evaluate the cleansing of previously unused 16 Fr Salem Sump tubes after infusion of feeding formula. Enteral formulas are suspensions,[2] and to avoid settling of dense and highly viscous particulates in the hanging containers, it was necessary to shake the container periodically during the 4-hour infusion experiments. Feeding formula was infused into a beaker, followed by automated standard water flushes. The tubes were then examined to determine the degree of cleansing. To evaluate the effect of acidification of the fluid that surrounded the distal end of the tube, tubes were placed horizontally at the bottom of a beaker. The beaker was anchored into a shaking water bath, with temperature at 37°C and mixing at 35 cycles per minute. Formula was infused at a rate of 20 mL/h. Saline (n = 17) or 0.1 N hydrochloric acid (n = 59) was infused into the beaker through a separate delivery system. Infusions were continued for 4 hours. Following infusion of formula, an automated water flush was delivered. The tubes were then clamped and gently removed from the beaker for examination. Osmolite (Abbott Nutrition, Abbott Laboratories, Columbus, OH), a casein-based formula, was selected for almost all experiments because it is the most commonly used enteral formula in our ICUs.

RESULTS

The length of the infusion channel of 16 Fr Salem Sump tubes is 122 cm. In contrast, the length of a 14 Fr feeding tube made by the same company is 91 cm. As shown in *Figure 2a*, cross-section revealed that the infusion channel of silicone 16 Fr Salem Sump tubes is not circular but oval, with a width of approximately 2.0 × 3.0 mm. The internal diameter of polyvinyl 16 Fr Salem Sump tubes is almost circular, approximately 2.7 mm. The diameter of the infusion channel of a 16 Fr Salem Sump tube *(Figure 2b)* is no greater than that of a 12 Fr single lumen nasogastric tube *(Figure 2e)*. As shown in the lower half of *Figure 2*, increasing the external diameter (French size) of single lumen tubes is associated with a comparable increase in the internal diameter of the infusion channel. In contrast, increasing the French size of double lumen Salem Sump tubes results in only a relatively slight increase in the internal diameter of the infusion channel.

Table 1 shows the demographic characteristics of each ICU patient whose obstructed tube was entered into our

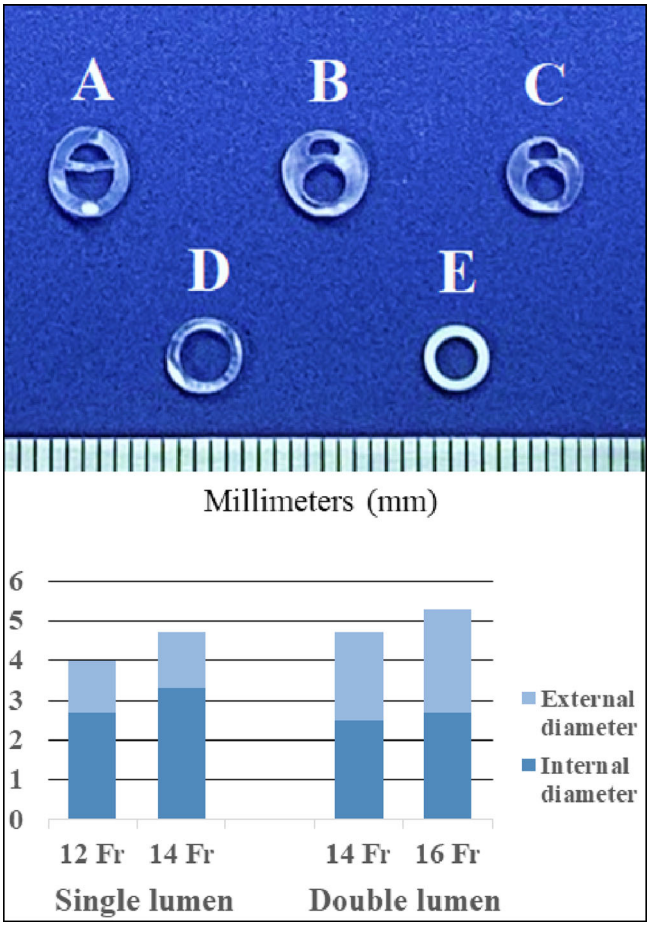

Figure 2. **Top.** Cross-sections of five nasogastric tubes that could be used to deliver nutrition and medications to ICU patients: **(a)** Covidien Salem Sump – 16 Fr, silicone, dual lumen stomach tube, infusion lumen is not circular (see text); **(b)** Covidien Salem Sump – 16 Fr, polyvinyl chloride, dual lumen stomach tube, internal diameter ~2.7 mm; **(c)** Covidien Salem Sump – 14 Fr, polyvinyl chloride, dual lumen stomach tube, internal diameter ~2.5 mm; **(d)** Covidien Kangaroo – 14 Fr polyurethane feeding tube, internal diameter ~3.3 mm; **(e)** Covidien Kangaroo – 12 Fr radiopaque polyurethane tube, internal diameter ~2.7 mm. **Bottom.** Effect of increasing French size on the internal diameter of single and double lumen nasogastric tubes. Increasing the external diameter of single lumen tubes (left) is associated with a comparable fractional increase in internal diameter. Increasing the external diameter of double lumen Salem Sump tubes (right) results in relatively little increase in internal diameter.

pathologic study. Patients are presented in groups according to the apparent origin of obstruction. Within each group, patients are presented in order of the date of tube obstruction. The large number of medications infused daily through these tubes consisted mainly of drugs the patients had been receiving orally prior to admission to the hospital.

As shown under the first heading of *Table 1*, in group 1 there were eight cases in which tube obstruction became apparent when a medication was being injected or during the subsequent water flush. In two of these eight cases (cases 2 and 7) of medication obstruction, pectin was the source of tube obstruction.[3,4] Although the US Food and Drug Administration does not consider it to be useful as an antidiarrheal treatment,[5,6] it is available as a dietary supplement (banana flakes) and is used to prevent or treat diarrhea associated with enteral nutrition. In case #2, obstruction developed shortly after pectin was infused into the tube, as Osmolite was restarted. In case #7, tube obstruction was noted during pectin infusion, before Osmolite was restarted. Clotted material was tan in color (similar to the color of banana flakes) and was mainly present in the lower half of the tubes *(Figure 3)*. In both cases, the clotted material was studied histologically and contained flake-like particles intermixed with amorphous and particulate material *(Figure 4a)*. In the other six cases of medication tube obstruction, the culprit medication could not be identified. The obstructing material was granular and white *(Figure 4b)*. In some cases, this material was examined microscopically, which revealed birefringent crystals suggesting compounding substances *(Figure 4c)*.

As shown in *Figure 3*, the most common site of medication-induced obstruction was between 40 and 80 cm above the distal end of the tube; no obstruction was present above the 80 cm level. In three cases, there were unclotted areas separating two or three clots. In three of these eight cases, there was an identifiable violation of recommended tube maintenance.[3] In cases #3 and #8, there was failure to flush medications with an appropriate volume of water. In case #16, medications were injected directly into ongoing formula infusion.

Group 2 consisted of seven cases in which tube obstruction developed in association with infusion of feeding formula or with water flushing after a period of formula infusion. In all seven cases, the obstructing clot was smooth and tan *(Figure 4d)*. Microscopic examination of the clot was done in some cases and revealed homogeneous material consistent with protein coagulation with no flakes or crystalline material *(Figure 4e)*. As shown in *Figure 3*, in six of the seven cases, there were clots in the distal chambers of the tubes that contain multiple apertures. In four of the seven cases, clots were also present in the mid-tube region, 50 to 70 cm from the tip of the tube. This pattern suggested that clotted formula begins in the distal chamber with multiple holes and that these propagate proximally into the body of the tube. No clots were attached to the outside of these obstructed tubes, but if clots were attached prior to tube withdrawal they could have been removed as the tube was pulled through the gastroesophageal junction, esophagus, and pharynx. We found no violations of recommended tube management in these seven cases. In case #14, tube obstruction occurred after a pause in formula infusion to allow a protein supplement to be administered, but this is not a violation of current guidelines.

In group 3, there were two cases in which we found no clotting or clogging within the infusion channel of the 16 Fr Salem Sump tubes. In both cases, obstruction was discovered following pauses in formula delivery, which were required for medical procedures. In case #6, the removed tube was completely normal. In case #9, the tube had a permanent kink 57 cm from the distal tip *(Figure 4f)*, and when the tube was forcibly held in a straight direction water flowed easily through it. Prior to removal, this kink would have been located near

Table 1. Patient demographics and history of obstructed 16 Fr Salem Sump tubes

NGT no.	Age/gender	Diagnosis	Tube type[a]	Gastric acid suppression	Feeding formula	Infusion days prior to obstruction	Daily meds through NGT: total/crushed	Clot dissolvent attempts
Group 1: Medication obstructions								
2[b]	77/F	CHF	S	H2RA (NGT)	Osmolite	9	10/8	1
3	75/F	Parotid cancer	S	No	None	NA	7/7	2
4	77/M	Ischemic stroke	S	No	Osmolite	1	5/5	2
7[b]	83/F	Pneumonia	S	H2RA (NGT)	Osmolite	9	2/2	0
8	27/F	Pneumonia	P	H2RA (NGT)	Osmolite	7	6/5	0
11	54/M	Pneumonia	P	No	Osmolite	5	5/5	2
12	39/M	Pneumonia	S	H2RA (NGT)	Promote	15	6/4	0
16	70/F	Lung cancer	S	PPI (IV)	Nepro	7	3/2	1
Group 2: Precipitated formula obstructions								
1	45/M	Pneumonia	P	No	Osmolite	4	2/1	0
5	67/M	Pneumonia	S	No	Promote	14	8/6	0
10	53/M	Sepsis	S	H2RA (NGT)	Osmolite	2	2/2	1
13	60/M	Pneumonia	P	H2RA (NGT)	Nepro	6	2/2	0
14	65/M	CHF	P	H2RA (IV)	Nepro	2	2/1	1
15	56/M	Cholangitis	P	H2RA (IV)	Nepro	7	6/6	1
17	52/F	Peripheral arterial disease	S	H2RA (NGT)	Nepro	1	4/2	0
Group 3: No intraluminal obstruction								
6	55/F	Encephalopathy	S	H2RA (NGT)	Osmolite	6	6/4	0
9	33/M	Alcohol withdrawal	S	H2RA (NGT)	Osmolite	4	4/3	1

[a]P indicates polyvinyl chloride Salem Sump tube; S, silicone Salem Sump tube.
[b]Cases 2 and 7 apparently developed tube obstruction due to pectin (banana flakes).
CHF indicates congestive heart failure; H2RA, histamine-2 receptor antagonist; IV, intravenous; NGT, nasogastric tube; PPI, proton pump inhibitor.

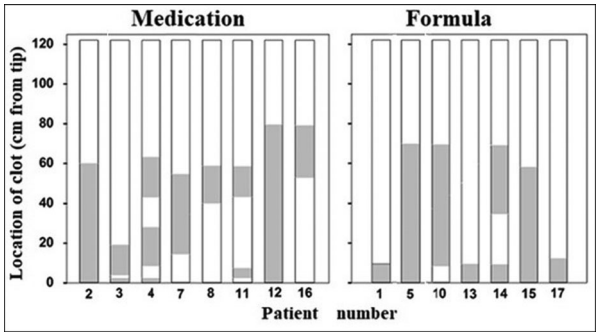

Figure 3. Location and extent of clotting in 16 Fr Salem Sump tubes removed from ICU patients. The vertical scale is from 0 (tip of tube) to 122 cm (top of tube or infusion port). See Table 1 for demographic data on each case. The figure does not show cases #6 and #9, whose tubes contained no internal obstruction.

the junction of the pharynx and the esophagus. There was no evidence in the medical records that the position of these tubes had been changed after initial insertion. However, as shown in *Table 1*, case #6 had encephalopathy and case #9 had alcohol withdrawal. It is possible that these tubes were manipulated during the pause for medical treatment, either by the patients themselves or inadvertently by caretakers.

In vitro studies were conducted to evaluate cleansing of 16 Fr Salem Sump tubes by water flushing. *Figure 5a* shows a tube infused with Osmolite for a 4-hour period but not flushed. *Figure 5b* shows a tube infused with Osmolite for 4 hours and then flushed with 30 mL of water; all of the infusion lumen contained diluted formula. *Figure 5c* shows the proximal and distal ends of a tube used to infuse Osmolite for 4 hours, followed by a 60 mL water flush. Proximal tube cleansing was consistently better with the 60 mL water flush, but the distal compartment remained nearly filled with Osmolite.

To elucidate the failure of 60 mL water flushing to cleanse the distal segment of these tubes, a silicone plug was inserted just below the proximal aperture; this created an air-tight obstruction between the single proximal aperture and the 10 distal apertures. After Osmolite infusion into a beaker for 4 hours, followed by a 60 mL water flush, there was heavy accumulation of unclotted Osmolite in the distal segment *(Figure 5d)*. We concluded that Osmolite contained in the excluded distal compartment after water flushing was

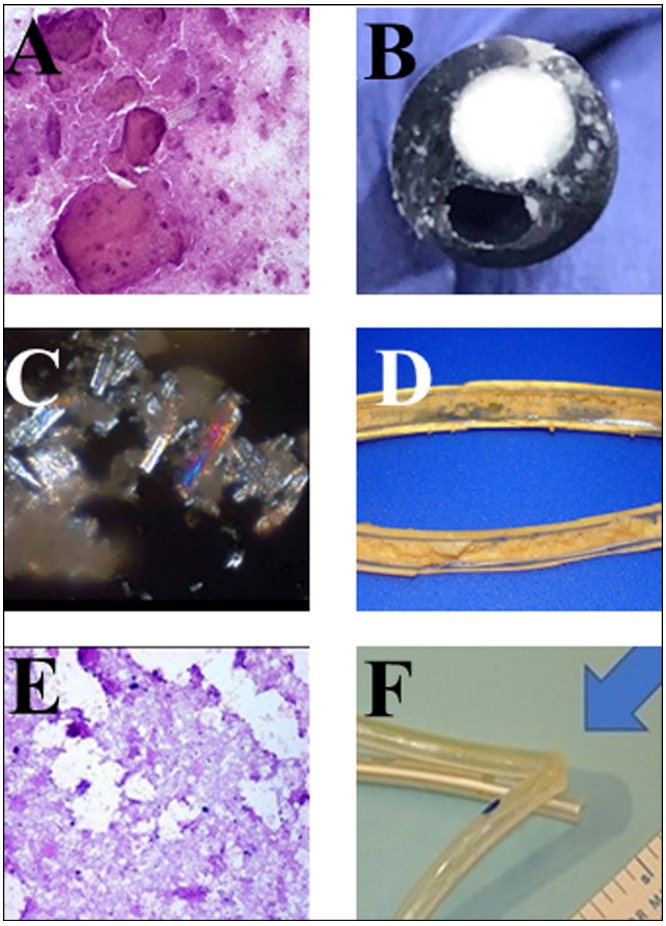

Figure 4. Pathology of 16 Fr Salem Sump tubes which became obstructed in ICUs. **(a)** Hematoxylin and eosin (400×) stain shows flake-like pectin particles from case #2. **(b)** Cross-section from case #3 reveals complete obstruction from white, chalky material. **(c)** Polarized light (400×) microscopic picture from case #3 shows birefringent crystals that are consistent with compounding agents of an administered medication. **(d)** A linear section of the tube from case #17 shows a smooth tan formula precipitation clot obstructing the distal 14 cm of the tube. **(e)** Hematoxylin and eosin (400×) stain of amorphous proteinaceous material from a formula precipitation clot (case #1). **(f)** Case #9, where a permanent kink (blue arrow) 57 cm from the distal tip of the tube apparently resulted in obstruction.

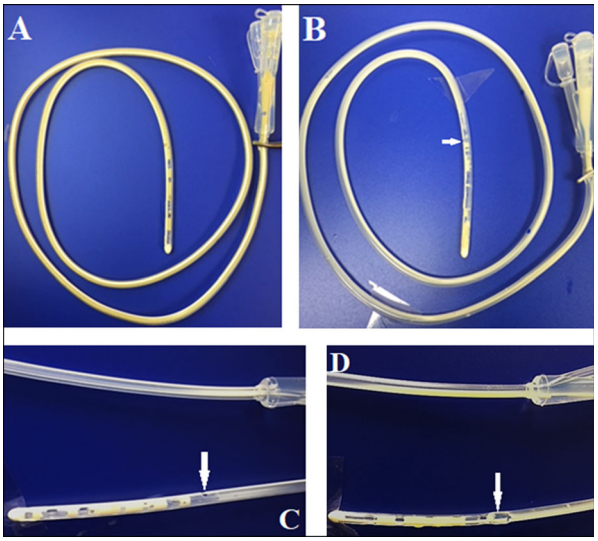

Figure 5. Effect of water flush on 16 Fr Salem Sump tubes in vitro. The top row shows entire tubes **(a)** filled with Osmolite, before flush, and **(b)** after 30 mL water flush, with diluted Osmolite present above the proximal aperture (arrow). More concentrated Osmolite is present within the distal chamber of the tube. The bottom row shows the proximal (top) and distal (bottom) ends of tubes after a 60 mL water flush. **(c)** The tube is better cleansed above the proximal aperture (arrow), but the distal compartment contains relatively concentrated Osmolite. **(d)** A silicone plug (arrow) was placed just distal to the proximal aperture, so Osmolite could not reach the distal chamber directly from the infusion channel. After a 60 mL water flush, the proximal tube is cleansed, but the distal chamber contains Osmolite.

derived from beaker fluid by retrograde diffusion through its multiple distal apertures.

It is known that acidification of casein-based feeding formula results in coagulation.[7–9] The pH of mixed beaker fluid during separated infusions of Osmolite and saline was 6.31 ± 0.13. The pH of beaker fluid during separated infusions of Osmolite and acid were as follows: 1.0 mEq/h acid infusion rate, pH 5.42 ± 0.17; 2.5 mEq/h acid infusion rate, pH 1.81 ± 0.14; 5.0 mEq/h acid infusion rate, pH 1.19 ± 0.04. After water flushing, the distal part of tubes were removed from the beaker and examined. When saline and Osmolite had been separately infused into the beaker, the external surface of the distal segment was clean. In contrast, when acid and Osmolite had been infused, the external surface of the distal part of the tube was covered by coagulated formula. This material could be easily removed by gentle wiping with soft paper, which then revealed clots within the distal end of the tube and obstruction of some of the distal apertures *(Figure 6a)*. The proximal aperture remained fully patent, possibly because almost all of the infused formula exited through it into the beaker. Results of these experiments were similar with silicone and polyvinyl chloride tubes. This same experiment was conducted with Salem Sump tubes that contained a leak-free plug between the proximal aperture and the distal apertures. As illustrated in *Figure 6b*, the isolated distal chamber contained abundant clots. We concluded that when acid and formula were infused separately into the beaker, both beaker acid and beaker formula entered the isolated distal compartment through its apertures and then coagulated within the distal compartment.

This reentry route was independently confirmed by injection of visible dye into the beaker and its subsequent presence within the distal infusion channel. When the distal chamber of the tube was removed by cutting and the infusion channel had a single aperture, coagulation still occurred around the distal end of the tube. However, water flushing cleansed the tube of residual formula *(Figure 6c)*, probably because continuous outward bulk flow of formula or water through the single aperture prevents retrograde movement of beaker contents.

The severity of casein clotting was qualitatively equal at the three acid infusion rates (1.0, 2.5, and 5.0 mEq/h). As expected from previous research,[7,8,10] a whey-based feeding formula did not coagulate upon acidification of beaker contents, and there was no clotting around the tubes or within their infusion channels.

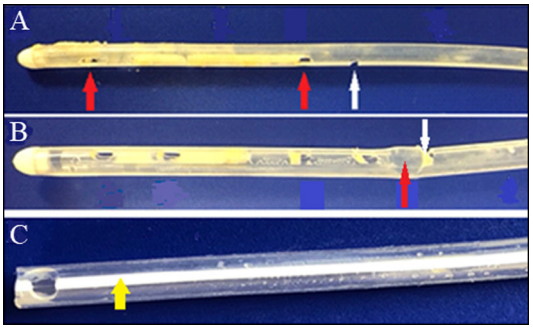

Figure 6. Appearance of the distal end of unmodified and modified 16 Fr Salem Sump tubes after separate infusions of Osmolite and acid (1 mEq/h HCl) into a beaker. **(a)** Distal end of the tube after all fluid drained by gravity. Above the proximal aperture (white arrow), the tube is empty. Below the proximal aperture, the tube contains clotted Osmolite within the infusion channel and only two of the distal apertures remain patent (red arrows). **(b)** A modified 16 Fr Salem Sump tube was created by inserting an air-tight silicone plug (red arrow) just distal to the proximal aperture (white arrow). This tube had been wiped and drained as described above. There were no clots within the proximal aperture or the infusion channel above it. The tube distal to the plug contained clotted Osmolite, and some of the apertures were obstructed. **(c)** A silicone plug was placed just distal to the proximal aperture, and the distal chamber with its multiple apertures was transected just below the plug. The modified tube contained a single aperture. The tube had been wiped and drained as described above. Despite acid-induced coagulation within the beaker and clots that surrounded the tube as in part (a) above, no formula clotting occurred within the infusion channel or in its single aperture. The solid white line (yellow arrow) is the radiopaque marker in the wall of the tube.

Table 2. Three reasons why 16 Fr Salem Sump tubes are not a good choice to deliver nutrition and medications in ICUs

1. The cross-sectional space used to include a nonfunctional air vent requires that the tube be relatively large in outside diameter (French size) and that the infusion channel be relatively small (small bore). Large French size increases pain of insertion, and small bore infusion channels increase the likelihood of tube obstruction.[3,7]
2. Multiple distal drainage holes cause accumulation of unwashable formula within the distal end of the infusion channel. These holes make the distal end of the tube difficult or impossible to cleanse by water flushing. Our in vitro studies indicate that they promote gastric acid reflux into the tube, which increases formula clotting and obstruction, especially when the tube is exposed to acidic fluid.
3. Multiple drainage holes at the distal end of the tube increase the total length of tube that must be inserted below the gastroesophageal junction, increasing the likelihood of serious injury, which is most likely when tubes are reinserted.[11,12]

DISCUSSION

As summarized in *Table 2*, the results of our research suggest that 16 Fr Salem Sump tubes are not a good choice to deliver medications and nutritional formula to ICU patients. Unfortunately, we have not found a commercially available tube that would avoid all of the negative features of 16 Fr Salem Sump tubes. However, we attempted to identify the best commercially available alternative. We suggest Tube D, shown in *Figure 2*. This single lumen tube has a smaller outside diameter (14 Fr) than a 16 Fr Salem Sump tube, which would reduce the risk of nasopharyngeal injury. Its larger internal diameter (3.3 mm) would reduce medication and formula obstructions.[3,7] It has only three unnecessary distal apertures which would unnecessarily extend the mandated depth of insertion by 4 cm instead of 8 cm. The length of Tube D is 30 cm shorter than that of Salem Sump tubes, which improves resistance to flow and provides better access when attempts are made to dislodge formula clots in obstructed tubes. Tube D is made of polyurethane, and its flexibility is between that of silicone and polyvinyl chloride tubes. Its quoted price, in response to our telephone inquiry, is $4.20 each, compared to $2.92 for 16 Fr Salem Sump tubes.

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